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Manufactured Soil Field Demonstration for Constructing Wetlands to Treat Acid Mine Drainage on Abandoned Minelands

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PURPOSE: This technical note provides information on the use of dredged material in manufacturing substrate for use in constructing wetlands to treat acid mine drainage from abandoned acid coal minelands.

BACKGROUND: The U.S. Army Corps of Engineers is responsible for maintaining navigation in all harbors and waterways across the United States. This task requires the dredging of more than 300 million yd^3 of sediment from the waterways annually. Places to dispose of these vast amounts of sediment are required. Most dredged material that is not suitable for open-water disposal usually is placed in confined disposal facilities (CDFs). Current CDFs are filling up and new CDFs are difficult to locate. In an effort to provide storage capacity for future dredging, dredged material in CDFs is being evaluated for beneficial uses. Cooperative research and development agreements (CRDAs) have been established with the U.S. Army Engineer Research and Development Center (ERDC), Environmental Laboratory (EL) to develop specific innovative technologies and demonstrate the application of these technologies to the reclamation and reuse of dredged material from existing CDFs. CRDAs have been established with Recycled Soil Manufacturing Technology (RSMT), N-Viro International (reconditioned sewage sludge biosolids), Bion Technologies, Inc. (reconditioned animal manures) and Advanced Remedial Mixing, Inc. (blending equipment for the reclamation of dredged material and other residuals). Examples of the reclamation and reuse of dredged material include manufactured substrates for constructing wetlands to improve water quality from abandoned acid mine drainage sites as well as nutrient rich agricultural runoff and/or drainage waters, Brownfields, and Superfund sites (Lee 2001). RSMT is an innovative patented technology that manufactures topsoil from residual waste materials such as dredged material, cellulose, and biosolids. This technical note describes the application of RSMT and the beneficial use of dredged material for restoration of abandoned acid coal mine drainage Brownfield sites through the development of constructed wetlands.

INTRODUCTION: ERDC teamed with an organization named AMD&ART to restore an abandoned acid mine drainage site at Vintondale, PA into a recreational park and passive remediation facility. AMD&ART is a non-profit organization that works with local communities striving to improve abandoned acid mine drainage sites through applying innovative technologies and incorporating art in the restoration plans. AMD&ART was interested in allowing ERDC an opportunity to apply RSMT to their acid mine drainage (AMD) site. Lee (2001) described the beneficial use of dredged material, waste paper fiber, and processed Class A cow manure (Bion-soil™) to restore the upland slopes of an abandoned AMD site at Vintondale, PA. That demonstration successfully planted 5,000 trees and shrubs in extremely acidic overburden soil. This

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opportunity also allowed material from the Donora, PA CDF to be blended with waste paper fiber and processed cow manure to produce a substrate to be used in the constructed wetland as a final polishing treatment for AMD. There are thousands of abandoned AMD sites in Pennsylvania alone, as well as many more sites in Ohio, West Virginia, and Kentucky. Demonstrating the beneficial uses of dredged material and other available residuals should create additional opportunities for constructing wetlands and the use of large quantities of dredged material.

The field site at Vintondale, PA was approximately 35 acres. The AMD treatment system included six sequential neutralization ponds and the "History Wetlands" (Figure 1). Between 50 and 200 gal of water per minute flow into Pond 1. The pH of water entering Pond 1 is between 2.9 and 4.5 and between 6.5 and 7.0 when it exits Pond 6. The color of selected native plants surrounding the sequential ponds transition from deep orange to silver-green, which parallels the increasing health of the water. A walking trail through the wetland includes physical markers as reminders of the site's industrial importance (AMD&ART, Inc. 1999). The "History Wetlands" consists of 7 acres of bony residual acid mine waste. Water flows from Pond 6 into Areas 1a, 1b, 2a, 2b, 3a, 3b, and 4, sequentially (Figure 1). The constructed wetland filters out suspended solids before water is discharged from Area 4 into Yellow Dog Creek and subsequently into the South Branch of Blacklick Creek. The two principal components of this study were: 1) the greenhouse phase, which evaluated dredged material and residual material mixtures; 2) the actual construction of the wetland.

METHODS: Dredged material from the Donora, PA CDF was used to manufacture a substrate for a constructed wetland (Tables 1 and 2). A variety of residual materials were available for constructing the wetlands including dredged material, residual waste paper fiber, sawdust, mushroom compost, cow manure, processed cow manure, and the residual acid coal mine overburden, referred to as "bony." An experimental design was developed to evaluate three constructed wetland substrates according to the proprietary formulation of RSMT:

1. Bony + Dredged Material + Waste Paper Fiber + Bionsoil™

2. Bony + Sawdust + Cow Manure

3. Bony + Waste Paper Fiber + Mushroom Compost + Bionsoil™

The RSMT procedures (Sturgis and Lee 1999) were applied in a randomized complete block design using the three blends above in addition to unamended dredged material, unamended bony material, and a control (commercial potting soil) (Figure 2). Vintondale blend contaminant concentrations are shown in Tables 1 and 2.

The data analysis evaluated the normality [i.e., Shapiro-Wilk's Test (Conover 1980)] and equality of variance [i.e., Levene's Test (Snedecor and Cochran 1980)] assumptions prior to utilizing the analysis of variance. The F test was utilized to determine if any of the means were significantly different. The Waller-Duncan k-ratio t-test identified the statistically different biomass means (Steel and Torrie 1980). All statistical tests were performed at $\alpha = 0.05$ level of significance.

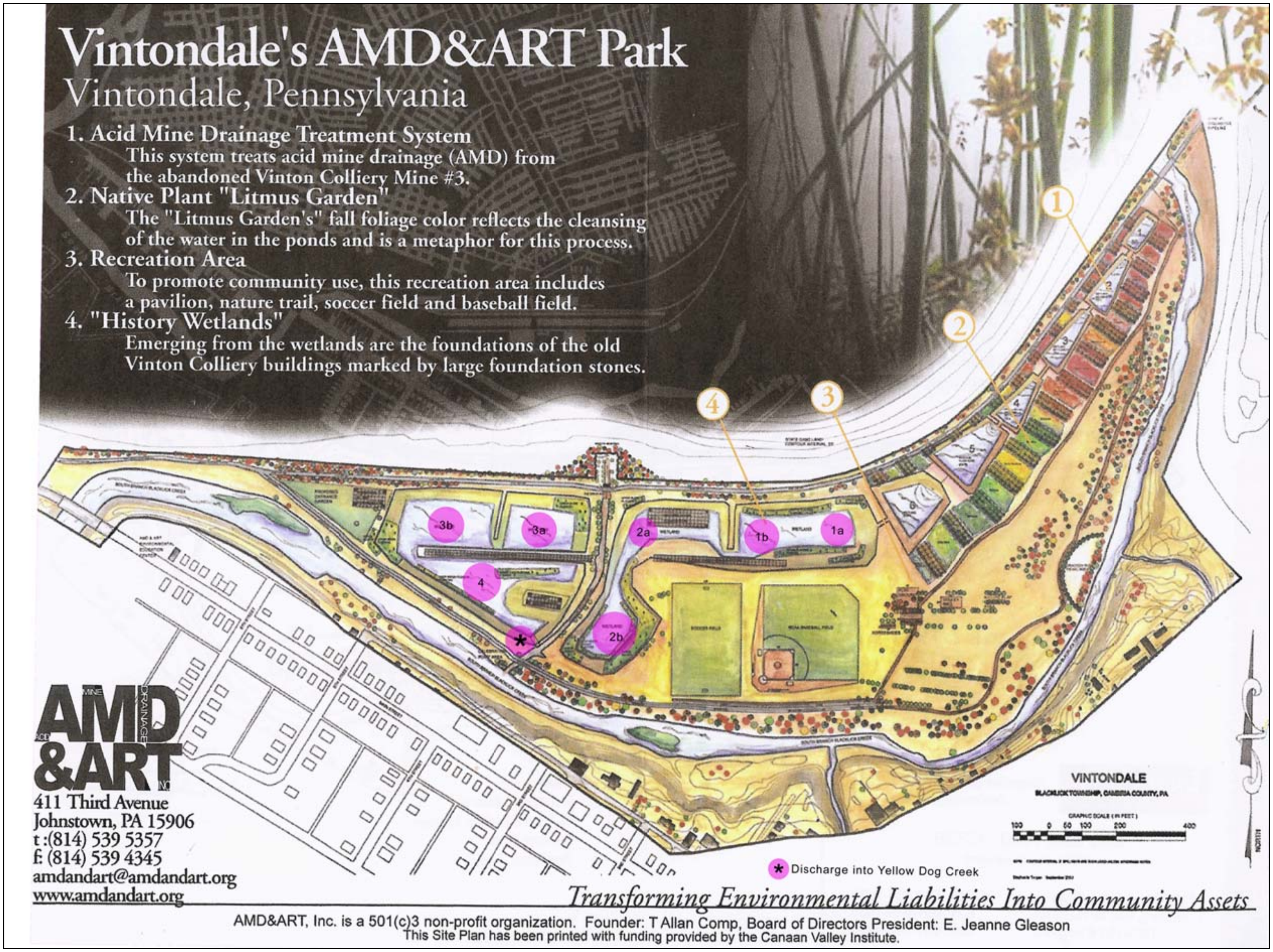

Figure 1. Vintondale AMD & ART Park.

Table 1
Donora, PA CDF Dredged Material and Vintondale Blend Selected Metals Concentrations

FIELD DESCRIPTION	SB	AS	BE	CD	CR	CU	PB	HG	NI	TL	ZN
DONORA,PA CDF *	<4.0	9.62	1.59	1.30	15.2 B	28.7	31.4	0.08	38.6	<6.0	214 B
VINTONDALE BLEND *	<4.0	20.0	0.64	0.38 J	12.5 B	90.0	40.8	0.39	11.3	<6.0	109 B

* units mg/kg

Table 2
Donora, PA CDF Dredged Material and Vintondale Blend PAH Concentrations[1]

FIELD DESCRIPTION	NAPHTH	ACENAY	ACENAP	FLUORE	PHENAN	ANTRAC	FLANTHE	PYRENE
DONORA, PA CDF @	2550	97.3	303	506	4190	1140	4440	3860
VINTONDALE BLEND @	672	29.1	177	250	1700	358	1640	1250
FIELD DESCRIPTION	**BAANTHR**	**BBFLANT**	**BKFLANT**	**BAPYRE**	**I123PYR**	**DBAHANT**	**B-GHI-PY**	**CHYYSE**
DONORA, PA CDF @	2670	1740	1690	2260	1430	300	1190	2610
VINTONDALE BLEND @	977	850	681	998	715	156	620	1380

@ units µg/kg
[1] Vintondale Blend includes Donora, PA CDF material, paper fiber, plus cow manure (Bionsoil).

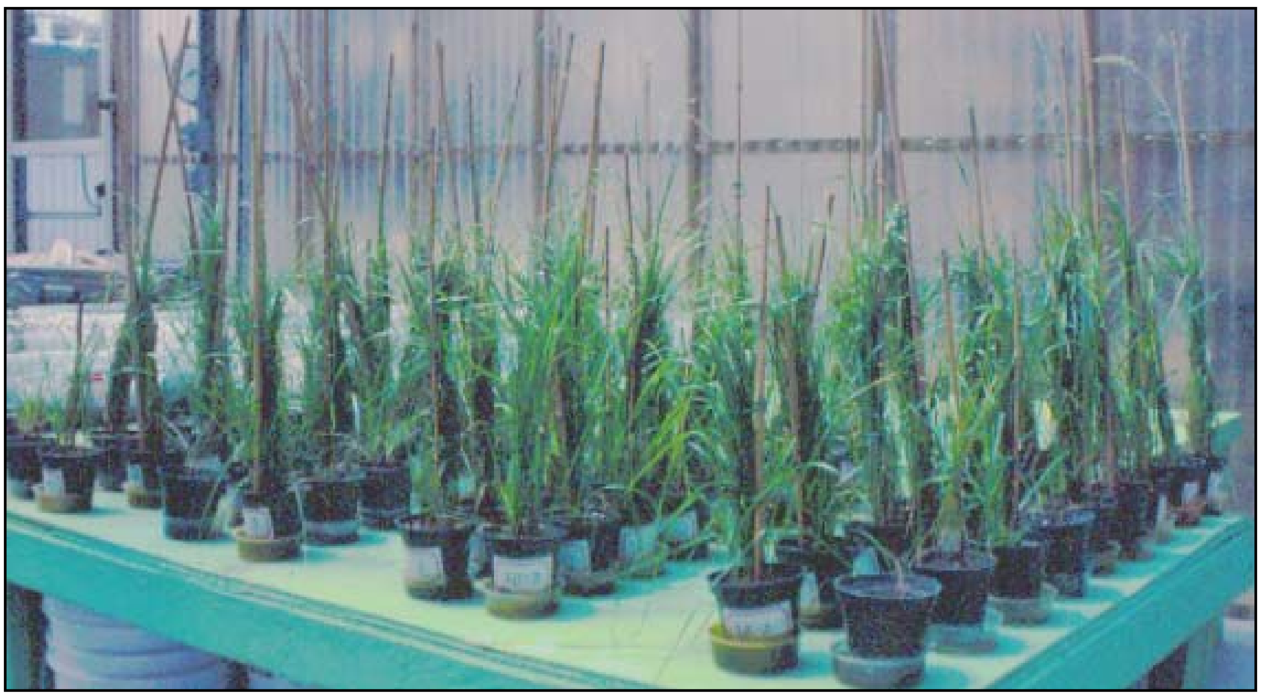

Figure 2. RSMT screening test in greenhouse.

GREENHOUSE RESULTS: Figure 3 displays one replicate of each treatment and the mean dry weights of four treatment replicates. Means which are not statistically different are followed by the same alphabet (i.e., Waller-Duncan k-ratio t-test results). RSMT blends 1BD and 2BD resulted in significantly higher yields than 100 percent Bony, 100 percent Donora, 3BD, and the

fertile commercial potting soil. Blend 1BD was selected for the constructed wetland field demonstration at Vintondale, PA, because it contained lower amounts of dredged material and therefore the cost of transporting material from the Donora, PA CDF to the site was lower. Transportation costs of materials are critical to the economics of beneficial uses of dredged material.

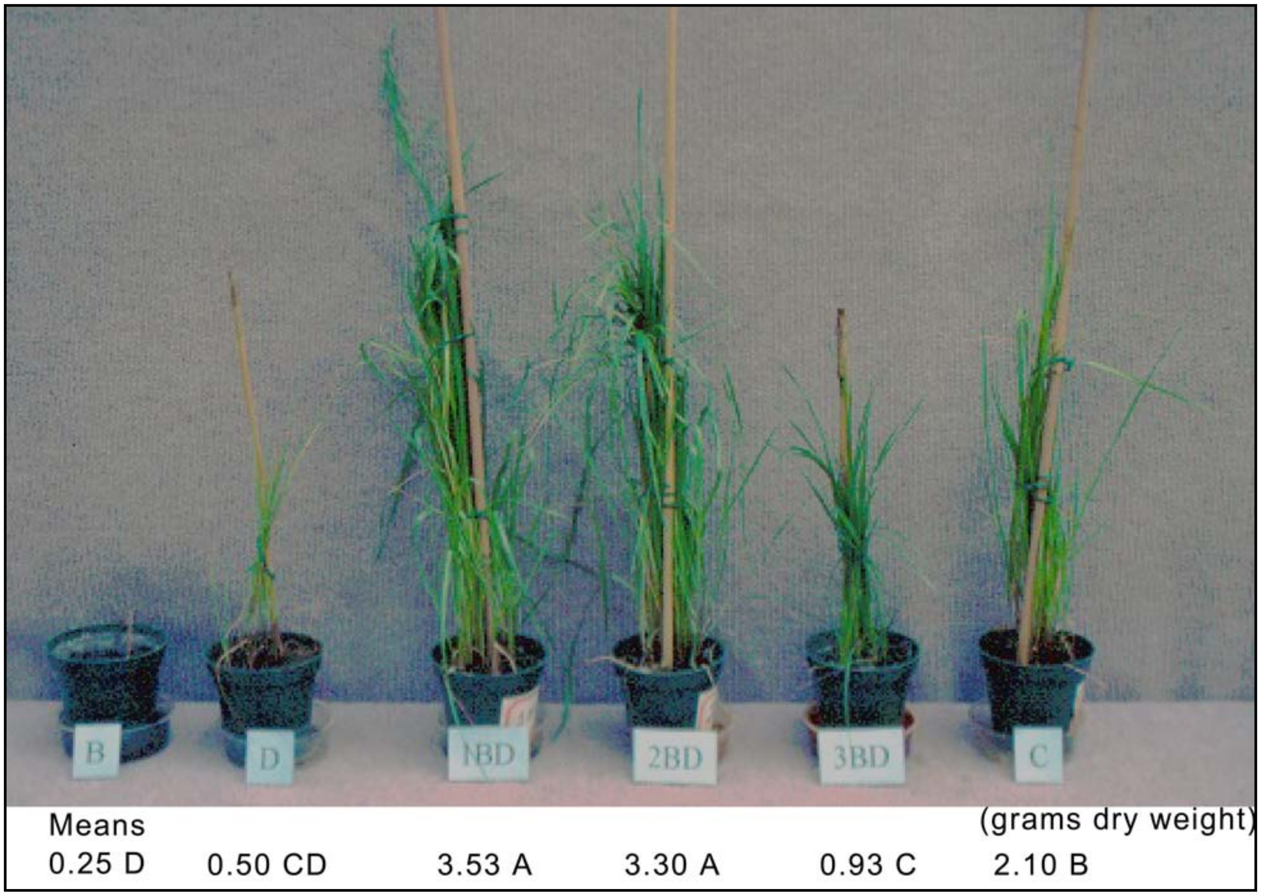

Figure 3. Ryegrass growth in bony (B), dredged material (D), and combinations of RSMT blends (1BD, 2BD, 3BD) and a fertile commercial potting soil (C).

CONSTRUCTED WETLAND: RSMT blended topsoil was used to provide a substrate for constructing wetlands in the existing bony residual material. The blend was essentially prepared by applying each residual material to specific areas and disking the applied materials into the existing bony coal mine residual waste. An application of 11.5 tons/acre of lime was placed on all areas to neutralize acidity. These substrates were prepared in August 2001.

The first constructed wetland (Areas 1a and 1b) consisted of sawdust and unprocessed cow manure incorporated into existing coal mine bony residual waste. Sawdust was loaded into a manure spreader with a front-end loader and spread across the bony residual in constructed wetland Areas 1a and 1b (Figure 4). Cow manure was loaded and spread across the area (Figure 5). The second constructed wetland (Area 2a) consisted of dredged material, waste paper fiber, and Bionsoil™ (a processed Class A cow manure biosolid). First, waste paper fiber was loaded into the manure spreader and then dredged material was placed on top of the paper fiber. Both

materials were then spread over the existing coal mine bony (Figure 6). Bionsoil^{TM} was then applied and all applied materials were disked into the existing bony.

Figure 4. Sawdust application to wetland Areas 1a and 1b.

Figure 5. Spreading cow manure applied to Areas 1a and 1b.

In the third constructed wetland (Areas 2b, 3a, 3b, and 4), waste paper fiber plus mushroom compost and Bionsoil^{TM} (i.e., a processed Class A cow manure biosolid) were applied to existing coal mine residual bony (Figure 7). Waste paper fiber was spread over the existing bony (Figures 8 and 9). Bionsoil^{TM} and mushroom compost (Figure 10) were then applied to the waste paper fiber and disked into the existing coal mine bony. A slow release fertilizer, Multicote^{TM} 17-5-11, was applied at a rate of 1,620 lb/acre to Areas 2a, 2b, 3a, 3b, and 4.

Figure 6. Dredged material/paper fiber applied to Wetland Area 2a.

Figure 7. Existing coal mine bony in Area 3a.

Wetland vegetation was planted according to the AMD&ART landscape design in November 2002. Acid mine drainage poured into the treatment ponds (Figure 11) and overflowed into the constructed wetlands (Figures 12-19). Wetland Areas 1a and 1b contained substrate blended from bony material and locally available sawdust and unprocessed cow manure (Figures 12 and 13). Area 2a (Figure 14) contained substrate blended from dredged material, waste paper fiber, and Bionsoil^{TM} (processed cow manure). Areas 2b, 3a, 3b and 4 contained a substrate blended

from bony, waste paper fiber, mushroom compost and Bionsoil™ (Figures 15-19). Periodic monitoring of water pH required by state regulators will be conducted to ensure appropriate water quality is discharged from the constructed wetlands into the South Branch Blacklick Creek (Figure 20). Comparing the physical appearance of areas in August 2001 and November 2003 (i.e., Figures 4 and 5 versus Figures 12 and 13, Figure 6 versus Figure 14, Figures 7 and 9 versus Figure 16, Figure 8 versus Figure 17, Figure 10 versus Figure 15) offers one measure of constructed wetland success. The vigorous appearance of the wetland vegetation has been maintained for approximately 12 months.

Figure 8. Applying waste paper fiber in Area 3b.

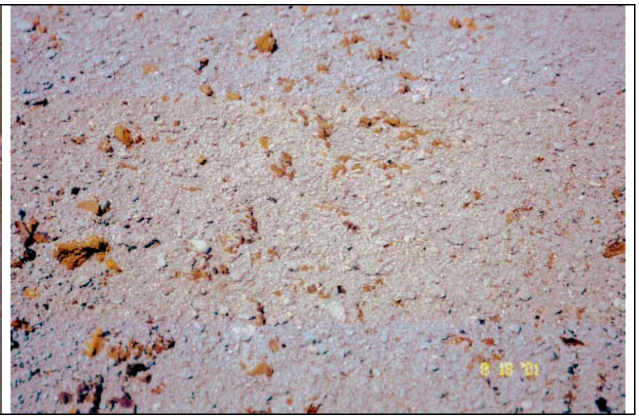

Figure 9. Cover of waste paper fiber over bony coal mine residue in Area 3a.

Figure 10. Mushroom compost applied to Wetland Area 2b.

Figure 11. Acid mine drainage passes through Pond 1, the first of six lime treatment ponds (Figure 1).

Figure 12. Wetland Area 1a blend consists of bony, sawdust, and unprocessed cow manure.

Figure 13. Wetland Area 1b.

Figure 14. Wetland Area 2a blend consists of dredged material, waste paper fiber, and Bionsoil™.

Figure 15. View over Wetland Area 2a to Wetland Area 2b.

Figure 16. Wetland Area 3a blend consists of bony, waste paper fiber, mushroom compost, and Bionsoil™.

Figure 17. Wetland area 3b blend consists of bony, waste paper fiber, mushroom compost, and Bionsoil™.

Figure 18. Treated water leaves wetland Area 3b and enters Area 4. The substrate blend consists of bony, waste paper fiber, mushroom compost and Bionsoil™.

Figure 19. Wetland Area 4 blend consists of bony, waste paper fiber, mushroom compost, and Bionsoil™.

Figure 20. Discharge outlet pipe from Area 4 into Yellow Dog Creek.

SUMMARY AND RECOMMENDATIONS: Recycled topsoil manufacturing technology (RSMT) using dredged material and available residual waste material such as waste paper fiber and biosolids (BionsoilTM) was used to devise a substrate blend capable of supporting wetland vegetation. The selected blend, 1BD, provided the maximum yield in greenhouse screening tests. The 1BD blend did not use the maximum amount of dredged material. However, for sites at a distance from the CDF, this lowers the transportation cost. The cost of transporting material is critical to the economics of using dredged material beneficially. The "History Wetlands" have been successfully restored based on physical appearance and function. The constructed wetland should improve water quality by filtering out suspended solids. Dredged material was very effective in the construction of wetlands. Comparing the unvegetated Area 2a (Figure 6) and the vegetated Area 2a (Figure 14) demonstrates the effect of RSMT blends. The vegetation in Areas 1a, 1b, 2a, 2b, 3a, 3b, and 4 has remained vigorous for approximately 12 months (Figures 12 through 20). The pH of water discharged from Area 4 should be monitored annually to ensure the pH remains between 6.5 and 7.0. Dredged material could potentially be used to restore thousands of abandoned acid coal mineland sites throughout Pennsylvania, Ohio, West Virginia, and Kentucky.

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